Progress in the Control of Air-Borne Infections*†

Committee on Research and Standards

SUBSTANTIAL progress has been made in the understanding of many problems in the field of air-borne infection during the three years since the previous association report (1947) on this subject.[1] Within the year, comprehensive reports[2-4] have been published in Great Britain, Sweden, and France, which not only report new studies, but which systematically review the field of sanitary ventilation and recognize its importance in public health. The major contributions to the progress of the field include:

1. Field studies on the control of air-borne infection by:
   A. Ultra-violet irradiation
   B. Triethylene glycol vapor
   C. Dust suppression
2. The mechanism and rate of action of germicidal vapors
3. The lethal effect of the intermediate range of relative humidity on bacteria- and virus-laden droplets sprayed into experimental rooms
4. The source and method of transmission of air-borne microörganisms and control through chemotherapy
5. The potential importance of the air-borne route in biological warfare
6. The commercial sale of glycol vaporizers

1. FIELD STUDIES

1-A—Ultra-violet irradiation

Continuing controlled studies[5-8] among recruits at United States Naval Training Centers have confirmed the earlier report that under barrack conditions a moderate reduction of approximately 20 per cent in the incidence of febrile respiratory admissions may be achieved through the use of ultra-violet irradiation. The effect is not constant, and the degree of reduction in incidence is not yet considered sufficient to warrant general use.

The further study[9] of ultra-violet irradiation at a boys' training school confirms earlier negative results. However, the conditions of the experiment were far less favorable for prevention than in the barracks studies.

Two reports have been submitted regarding the use of ultra-violet light in rural schools in New York State. The first[10] indicated that the velocity of spread of measles among pupils of irradiated classrooms was remarkably slowed down even though the total number of cases was not observed to be diminished. A subsequent report[11] from the same schools on the irradiation in chickenpox and mumps also suggested a slower velocity of spread. Furthermore, the incidence of each disease over a 4 year period was lower among pupils in irradiated classrooms. However, because of many variables and certain inconsistencies, it was not possible to conclude that the lowered 4 year incidence among these school children was related to irradiation. These results harmonize with those in earlier studies on irradiation in day schools in indicating

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* Report of the Subcommittee.

SUBCOMMITTEE ON AIR SANITATION OF THE COMMITTEE ON RESEARCH AND STANDARDS (Formerly the Subcommittee for the Evaluation of Methods To Control Air-borne Infection)
Organized 1948.

† Prepared and presented by Hollis S. Ingraham, M.D., October 26, 1949.

that the velocity of spread of certain communicable diseases may be lowered in irradiated classrooms. However, since irradiation of the classroom does not prevent the spread of these diseases outside the classroom, school irradiation cannot yet be deemed a practical measure. Further studies of this subject, with especial attention to the channels of spread through the community, are urgently needed.

One additional report [12] is available as to the use of ultra-violet irradiation in preventing the transfer of infection among hospitalized children. This study, although based on rather small numbers, would strongly suggest that ultra-violet light is of considerable value in reducing the frequency of cross-infection in infant wards. This is confirmatory of the bulk of previous studies. The sum total of evidence then, in infant wards, seems to be that when strict aseptic conditions are maintained, ultra-violet irradiation further reduces the frequency of cross-infection.

1-B—Triethylene glycol vapor

In the past three years several additional field trials on the efficiency of triethylene glycol vapor in lowering respiratory disease incidence have been reported. One study,[13] on the control of air-borne infections among Army Air Force recruits at Chanute Field, Illinois, yielded questionably significant results. Likewise, the study [14] on the control of cross-infections in an infants' ward, although favorable, was not conclusive. A third report,[15] on the attempted control of colds among office workers, did not reveal any positive effects. Hence, from a practical standpoint, there is relatively little new information available as to the conditions under which triethylene glycol may be expected to be effective in the reduction of air-borne infection.[16]

1-C—Dust Suppression

Practical methods for reducing the intensity of dust-borne organisms from bedclothes and floors, developed during the war, were covered in the 1947 report.[17, 18] Several studies as to the effectiveness of dust control in barracks and hospitals have been published during the past three years.[6, 19-21] These studies have not been conclusive or entirely consistent but, in conjunction with previous studies and experimental work, would suggest that under certain, but as yet poorly defined, circumstances, some types of spread of air-borne disease may be partially suppressed by means of dust control. On the whole, it appears that dust control alone will not prove to be of great value as a general method of control of air-borne disease. Since organisms arising from dust reservoirs have been found to be relatively resistant to the action of germicidal vapors and ultra-violet irradiation, dust suppressive measures are desirable adjuncts to these techniques in efforts to prevent air-borne infection.

2. MECHANISM AND RATE OF ACTION OF GERMICIDAL VAPORS

During recent years, a number of substances have been demonstrated to have a powerful bactericidal action in the air. The majority of these materials have been studied either by English workers [2] or by the University of Chicago group in this country [16, 22-28]; among them are the halogens, hypochlorites, lactic acid and other hydroxy acids, hexylresorcinol, and the glycols. Of these chemicals, the glycols have been most intensively studied and appear presently to have the fewest drawbacks as germicidal vapors. Triethylene glycol is the substance now under most intensive investigation. It has been shown to be effective against a wide variety of pathogenic bacteria ordinarily found in the air, and also to be lethal to a number of filterable viruses. Several recent reports [29-31] have added to the number of microörganisms known to be susceptible to triethylene glycol.

All evidence to date indicates that triethylene glycol is not toxic under such conditions as might reasonably be expected to be encountered in its employment as a germicidal vapor.[23]

During the past three years, a large amount of work[2, 22-25] has been performed in the laboratory, which has resulted in the further elucidation of the mechanism of action of glycol and other germicidal vapors. The action of any water soluble germicidal vapor depends upon the relative humidity and the inherent toxicity of the germicide for bacterial metabolism. At a high relative humidity, the equilibrium concentration of germicide, which is attained by condensation on the bacterial particle, is low because of the high water content, and hence germicidal action is diminished. Conversely, at an extremely low relative humidity, the water content of the particle containing the infectious agent may be so low that negligible condensation of the germicide would occur, and again diminution in the germicidal action is observed. At intermediate humidities, lethal concentrations of the germicide readily accumulate on the particles, and the germicidal action is maximum and may occur within a matter of seconds.[28]

Fortunately, in the case of triethylene glycol, the relative humidity within which the greatest germicidal action is observed is in the range of 20 to 50 per cent,[28] which is that variation ordinarily found in occupied spaces during the winter months. The action of triethylene glycol depends more closely upon the relative saturation in the air than upon its absolute concentration. Saturations of glycol below 50 per cent become progressively less effective. As the concentration of glycol vapor in the air approaches saturation, a fog will appear. There is no danger inherent in the presence of such a fog and it may represent the only means of ascertaining the presence in the air of bactericidal concentrations of triethylene glycol vapor.

Efforts to use triethylene glycol experimentally have been seriously hampered up to the present by the lack of any commercially available device for easily and accurately measuring the glycol concentration and saturation in the air.

3. LETHAL EFFECT OF HUMIDITY

Control of the relative humidity in the environment is necessary for the proper use of germicidal vapors for aerial disinfection and may be a significant factor in determining the efficacy of ultra-violet irradiation. A recent study,[32] however, reported that, under carefully controlled experimental conditions, relative humidity alone in narrow intermediate ranges centering about 50 per cent was lethal to air-borne microörganisms. Humidities above or below these ranges revealed no such germicidal influence. The organisms found susceptible to this lethal effect of humidity were pneumococci, staphylococci, and streptococci and, in a later report,[33] influenza virus, PR8 strain, was found to behave in a similar fashion. The lethal effect of humidity was shown to be dependent upon the presence of sodium chloride in the saliva or suspending medium and was thought to be related to the rate of evaporation occurring in the atomized droplets at the critical intermediate humidities.

Under experimental conditions, the rate of disinfection occurring at optimum relative humidities approached that observed for other methods of aerial disinfection. However, it must be emphasized that these data were obtained from strictly controlled laboratory experiments, and as yet nothing is known as to the possible significance of this mechanism in air sanitation under field conditions.

4. SOURCE OF AIR-BORNE BACTERIA AND EFFECT OF CHEMOTHERAPY

It is now well established[2, 17, 18] that individuals continually extrude bacteria into their environment during the course of talking, laughing, sneezing, or coughing. If pathogens are present, the contamination of the air and dust by these agents may reach a high degree. Recent studies[34-36] reveal that droplets from man's respiratory tract range from 1 to 2,000 microns in diameter, the most common being 4 to 8 microns. In the smaller droplets and droplet nuclei, the number of microörganisms in each droplet must, of necessity, be small or indeed absent. Other studies[37-40] are confirmatory and show that the number of organisms expelled varies according to respiratory tract activity. Only by sneezing or violent coughing does the carrier of pathogens ordinary contaminate his immediate atmosphere to any great extent directly from his mouth and nose.

The mechanisms of contamination of the environment by nasal dispersers of hemolytic streptococci show that the act of blowing the nose with secondary dispersal of the bacteria from dried secretions on handkerchiefs,[40] clothes, or hands, is most important. In hospital wards and barracks, in which nasal dispersers of hemolytic streptococci were present, only occasional hemolytic streptococci could be isolated from the air during quiet periods, whereas large numbers could be recovered from the air during periods of bed making and floor sweeping.[39, 41, 42] It is also well known that other bacteria, particularly tubercle bacilli and diphtheria, and certain viruses, may thus persist in dust, and recently it was reported[43] that smallpox virus could also so survive for many months.

Despite the much greater abundance of certain bacteria in the dust, the relative role of droplet nuclei, droplets, dust-borne particles or contact with the disperser in the spread of human infection is not known.

Recent research, however,[44] showed that tubercle bacilli inhaled in droplet nuclei reached the lungs, forming tubercles lethal to rabbits, while those in particles as coarse as household dust could be breathed almost with impunity, being filtered out in the upper respiratory tract.

These studies emphasize the multiple potential modes of spread of so-called air-borne disease by contact with agents in a contaminated environment.

The intensive treatment of nasal carriers of hemolytic streptococci[45] by penicillin resulted in a marked diminution of the rate of elimination of the organisms with a resultant lowered contamination of the environment. A similar effect has been observed as a result of chemotherapy of other respiratory diseases and this may be expected to be a factor to be considered in future studies on air-borne infection. Obviously, the control of reservoirs of infection by chemotherapy is not of general application, but can only be considered under special circumstances over a relatively short period of time.

5. BIOLOGICAL WARFARE

An increasing number of reports[30, 46-49] indicate that, in the event of future hostilities, biological warfare may become a serious public health problem.

These reports further suggest that the air-borne route of spread may be employed. This possibility must be given consideration in any attempt to evaluate the ultimate worth of studies in the control of air-borne disease.

At the present time the subcommittee is unaware of any program to familiarize civilian health authorities with what steps, if any, need to be taken to plan for the protection of the civilian population against the threat of biological warfare.[50] It would seem of utmost importance that the federal government should make available to local authorities overall plans for dealing with biological warfare so that the latter, in turn, may review this problem in the light of their own situation.

6. COMMERCIAL SALE OF GLYCOL VAPORIZERS

During the past two years, a wide variety of glycol vaporizers has been made available commercially.[51] These are being advertised for use in public meeting places and in the home. The popular articles[52] and advertising brochures imply that glycol vapors are effective in preventing many infectious diseases, especially the common cold. Many of these claims exceed the bounds of present scientific evidence.

Before any method for the environmental control of air-borne infection can be recommended, it must be established:

1. That the active agent is effective against pathogenic air-borne microörganisms;
2. That the equipment will maintain an effective concentration of the agent under continuous field use;
3. That there is freedom from toxicity, corrosiveness, or other deleterious effects;
4. That under conditions for which the method is recommended, an actual lessened incidence of disease can be demonstrated.

With regard to glycol vaporizers, these conditions are not being met at the present time. While the lack of toxicity of triethylene glycol is reasonably established, and its germicidal efficiency in the laboratory is impressive, its effectiveness under various field conditions remains to be demonstrated. This failure in the field may be due to several factors, among which are, (a) the difficulty of maintaining continuous germicidal concentrations with presently available equipment; (b) the relative ineffectiveness of the vapor on bacteria-laden dust particles; and (c) the probability that direct contact or droplet spread of infection may occur within the treated space; and (d) the opportunities for acquiring infection through exposure outside the treated environment.

There is no assurance that all of the vaporizers on the market are capable of maintaining a satisfactory concentration of glycol vapor. It is to be regretted that, up to the present time, no agency has set up standards for acceptance of these devices, such as have been established by the Council on Physical Medicine of the American Medical Association for instruments designed for ultraviolet irradiation.

POTENTIALITIES FOR FUTURE CONTROL OF AIR-BORNE INFECTIONS

The relative importance of the air-borne route of infection has not yet been quantified in any of the common communicable diseases of man. In certain specialized environments, however, the potentialities of controlling air-borne infection are real. In research laboratories, working with the agent of certain highly infectious diseases, such as Q fever or psittacosis, the danger of air-borne infection is well established. A certain residual number of cross-infections may result from aerial infection in operating rooms, in pediatric and contagious disease wards where rigid aseptic precautions to prevent contact infections are maintained. The air-borne route of infection may also be a factor in the epidemics of acute respiratory and contagious diseases that frequently occur in institutions, in schools, and among recruits. In these restricted populations, the conduct of well controlled field studies offers the best prospects for the logical development of methods to control air-borne infections.

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